Office of Fossil Energy

eye on environment

Photo credit: Terry Ackman, NETL

NETL's Advanced E&P Technology Research Promotes Environmental Protection

Exploration and production trends in recent years have stressed, "*Smarter, Farther, Deeper, Cleaner*" and the newest trend is *"Smaller"*. NETL's research has helped to develop more efficient E&P technologies that allow industry to drill fewer holes and still produce more oil and gas. Today the industry is able to add 2 to 4 times more oil and gas to the nation's reserve base per new well than in the 1980's. These improved technologies result in fewer waste products from each well; fewer and smaller wells result in less surface disturbance.

Smarter	Intelligent computing, "smart wells"
Farther	Horizontal wells, multiple laterals
Deeper	Deep offshore, subsalt exploration
Cleaner	Improved refineries, Gas-to-liquids conversion, downhole separator
Smaller	Footprint, reduced environmental impact, microhole technology

Technological Advances

Technology advances are making exploration, development, production, processing and distribution of oil and natural gas cheaper, more efficient, and more protective of the environment. Advances come under the headings of: 1) exploration, 2) drilling, completion and stimulation, 3) production, 4) operations. DOE funded projects have developed, tested, adapted and implemented field demonstrations of many of the technological advances introduced to the petroleum in the past 20 years.

Major contributions to future domestic supplies must come from new frontiers in such geologically challenging and operationally complex settings as the Alaskan North Slope, deep formations, deepwater offshore, and lower permeability formations in the Rocky Mountain States. Today's producers are applying a host of new technologies and strategies to minimize the environmental impact of oil and natural gas operations in these frontier regions. DOE sponsored projects are providing solutions to meet the challenges of working in sensitive environments, such as the tundra, arid plains (**Figure 1**), and coastal areas by developing and demonstrating new advanced technologies.

DOE's Oil E&P program has focused on developing technologies to find new reserves, improve drilling efficiency, reduce costs, increase production through enhanced recovery methods, and prevent mature domestic fields from abandonment. These improved technologies and strategies have environmental benefits.

Advanced Technology Issue

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This Edition of Eye on Environment Highlights Environmental Benefits of the Exploration and Production Program

BENEFITS:

Innovative E&P technologies and strategies have had positive environmental benefits in reduced impact on lands, surface waters and aquifers, wildlife, and air quality. The overall push to improve E&P has led to more efficient methods; which increase the use of remote sensing exploration, reduce the size of well pads, limit excess roads and surface facilities, decrease the volume of produced water and reinject much of it, reduce the number of wells drilled (fewer dry holes, more multilateral wells), and actively promote environmental considerations in exploration and production practices.

Photo credit: Lee Gerhard

Figure 1. ***To improve the public's perception of the petroleum industry, efforts are made to reduce the visual impact by painting oilfield equipment to blend into the environment.***

EXPLORATION

Exploration for oil and gas has advanced tremendously is the past two decades. Seismic technology has evolved from simple 2-D surveys to complex 3-D and 4-D surveys capable of locating reservoirs at great depths, under salt or other structures and mapping migration of fluid saturations. Satellite imagery and aeromagnetic surveys have added to the ability to analyze potential reserves and monitor fluids with little or no surface impact. Intelligent computing software has significantly improved exploration methods.

BENEFITS:

The environmental benefit of reduced drilling footprint is illustrated in several exploration projects. Technologies which allow the operator to reduce the number of wells they drill to optimize production results in fewer acres of land disturbed. Targeted horizontal wells (to produce the same volume of oil as multiple conventional vertical drilling) can reduce the number of wells in or around sensitive areas, or can penetrate under these areas without disturbing the surface. In arid climates such as the Williston Basin a single horizontal well may cut the number of wells and their associated roads by factors of three to ten. Fewer roads also mean less impact on native animal species and their breeding and migration areas.

Luff Exploration of Denver, CO continued research in the Red River formation of the Williston Basin in North and South Dakota and Montana has led to the development of an Intelligent Computing System (ICS). ICS has been developed as a tool to assist decision makers in selection of optimal drill-site locations, to reduce risks associated with drilling operations and to reduce the number of dry holes drilled. ICS uses clustering, artificial neural networks, and classical regression methods to combine existing seismic, geologic and engineering data for predictions of reservoir potential. Based on ICS analysis, Luff converted 16 vertical wells to horizontals resulting in a 10-fold increase in production with no new wells being drilled. This simultaneously reduced the drilling footprint, and increased reserves and recovery in the Williston Basin. The software is not specific to any region and can easily be applied to other mature fields and basins in the US to improve economics and reduce environmental impact.

Advanced Resources International has identified new resources on the Fort Berthold Indian Reservation by using advanced seismic technologies to identify trapped oil in formations under Lake Sakakawea (**Figure 2**). The Three Affiliated Tribes-Mandan, Arikara and Hidatsa–have 150,000 acres of tribal lands that lie beneath Lake Sakakawea, a reservoir created when the Missouri River was dammed in 1951. The DOE program provided the funds to purchase 200 miles of seismic, Landsat and aero-magnetic data covering the area around and beneath the lake. Ten structural leads that are accessible by horizontal wellbores have been identified beneath the narrow, sinuous lake. Horizontal wells will allow the tribe to access this rich new resource with minimal impact to the fragile arid lands surrounding the lake.

BENEFITS:

The cost of a dry hole is easy to see in economic terms, in environmental terms it may be less obvious. Essentially each dry hole results in another well being drilled to attempt to establish production. Exploration and between well monitoring technologies can result in fewer dry holes, and thus reduced environmental impact.

Figure 2. ***New exploration and drilling strategies allow exploration and development under Lake Sakakawea, while preserving and arid high plains environment.***

Crosswell electromagnetic logging tools developed by ElectroMagnetic Instruments and Lawrence Livermore National Laboratory are leading to more efficient exploration, well monitoring and reducing the number of dry holes. Crosswell electromagnetic imaging tools provide the resolution to accurately map fluid properties in the areas between wells that has been missing from conventional seismic analysis. Crosswell imaging has been successfully tested in waterfloods and steamfloods in California, and to monitor CO_2 floods in New Mexico. The tools (**Figure 3**) are moved up and down in neighboring wellbores, and have the ability to image uncased wells, and through fiberglass and steel well casings. The latest development is a design which will allow the tool to image the area surrounding the wellbore through a single well, which will significantly reduce logging costs, and is particularly important for deep offshore wells. Thru-casing, single-well imaging can result in fewer wells to explore and plan offshore development. Crosswell imaging can significantly reduce the number of exploratory wells, and reduce surface impact during oil field production due to improved monitoring of water, steam and CO_2 injection.

Photo credit: Lawrence Livermore National Lab.

Figure 3. ***Crosswell transmitters and receivers can reduce the number of wells for exploration and monitoring water, steam and CO_2 flood operations.***

BENEFITS:

Technologies that improve monitoring in deepwater offshore wells have the additional advantage that can reduce unnecessary drilling and testing procedures. Crosswell imaging and Subsalt imaging both reduce the number of exploratory wells necessary to model the reservoir and assist in prediction of the best location of development well.

Sandia National Laboratory is conducting research designed to enhance the understanding of the forces subsurface salt bodies exert on oil and gas wells, and provide technologies to counter the effects of salt deformation in the deepwater Gulf of Mexico. Salt deformation may result in severe damage to wellbore and equipment through lateral motion resulting in shear and twisting action, and may cause hydrocarbon leaks into the ocean. Research conducted by Sandia is designed to enhance the understanding of the stress fields associated with salt diapers and the forces that subsurface salt bodies exert on oil and gas wells, and provide technologies to counter the effects of salt deformation. The research shows how to more accurately plan subsalt wells that penetrate massive salt diapirs, and how to design robust well casings to resist salt movement. The 3-D visualization

software and casing design tested at Mad Dog field and Thunder Horse North field (**Figure 4**) operated by BP America with multiple partners reduced costs by $30 million dollars, and potential hydrocarbon leakage into the waters of the Gulf of Mexico was avoided. The project focus on identifying, quantifying, and mitigating potential well integrity issues associated with subsalt and near-salt deepwater Gulf of Mexico reservoirs.

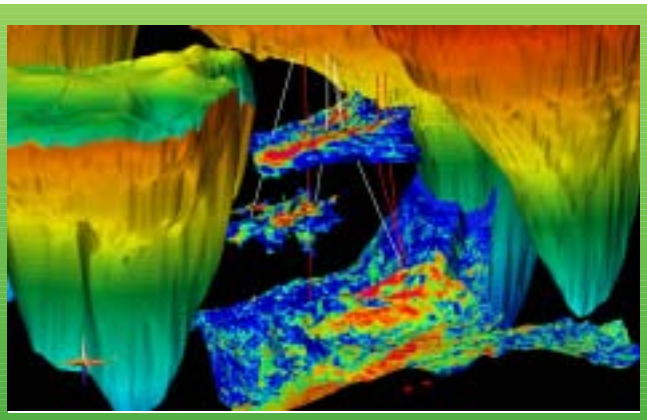

Photo credit: BP America

Figure 4. ***Computer model showing the effects of salt diapers (tooth shaped) adjacent to stacked reservoir sands are used to target safer drilling locations.***

BENEFITS:

Computer models and more robust well casings can prevent pollution of the ocean by drilling fluids and hydrocarbons resulting from damage to wellbores caused by salt deformation. Identification of safer well locations and new designs to strengthen the well casing will prevent casing leaks, which could damage the marine ecosystem.

DRILLING

Innovations in drilling technology have significantly reduced the environmental impact in recent years. DOE projects have been in the forefront of sponsoring technologies which use smaller drilling pads, directional drilling, smart wells, slimhole/microholes, coiled tubing, and measurement while drilling technologies. Exploration technologies assist drilling operations to be more effective by providing better targets for the new drilling procedures. The innovative exploration and drilling technologies applied together can produce more oil and gas from fewer wells. Fewer wells means less land disturbed by drilling operations and the associated surface infrastructure and transportation systems. Microhole drilling and completion technologies are the focus of a major effort in 2004-2005 in DOE's E&P oil program.

BENEFITS:

Microhole drilling opens up a domestic resource of 218 billion barrels of oil found at depths of less than 5,000 ft. In the future microhole drilling will be conducted using helicopter transport to field sites, which will further reduce the footprint and reduce environmental disturbance. The small rig size also contributes to the reduced visual impact of drilling that has caused public objections in some areas. Helicopter transport of equipment, materials and personnel to sensitive areas will benefit the wildlife and ecosystems by eliminating contact. This is particularly important to migrating species and species which require specific areas for calving grounds or nesting.

Los Alamos National Laboratory and the Rocky Mountain Oilfield Testing Center (RMOTC) are working together to develop a microwell program for drilling and completing wells with diameters of less than 3 inches. The RMOTC site near Casper, Wyoming has over 10,000 acres of federally managed lands and hundreds of existing wells with seismic and reservoir data providing an excellent area to test new drilling and completion technologies. Los Alamos has designed advanced sensors for use in microborehole using miniaturized hardware and coiled tubing, and a small microhole drilling apparatus (**Figure 5**) which can be transported on a small truck. The drilling equipment is small, easily transportable and the supplies needed to complete wells are likewise reduced. The overall impact of microholes is to reduce the drilling footprint. The small drilling pads and minimal facilities required for exploratory drilling and production are specially designed for sensitive environments like the arid Rocky Mountain States.

Northwest Alaska Native Association (NANA) representing 13 native corporations owned by 11,000 Inupait shareholders living in remote villages in Alaska. The NANA project has demonstrated the

use of mobile, small footprint drilling and completion equipment for exploration and production in remote areas. The vast resource of unconventional gas, estimated at 1,000 Tcf of coalbed natural gas, shale gas, and tight gas sands is often found in sensitive areas.

Photo credit: Los Alamos National Lab.

Figure 5. ***The small size of microhole drilling units can significantly reduce the environment footprint.***

The Slimhole drilling equipment (3.50 inch borehole), all necessary completion fluids and muds, and personnel can be transported by helicopter to individual sites for drilling and well completion. One of the challenges to be met was the selection of an antifreeze, which would allow the borehole to remain open in the permafrost for up to four days. Propylene glycol was selected for its good freeze depression characteristics, lack of health risks, and because it is biodegradable. Transportation of the light-weight drilling equipment and reduced volumes of supplies by helicopter eliminated road building and later reclamation of the surface (**Figure 6**). The small well pad and lack of roads will also reduce wildlife and habitat disturbance. Slimhole drilling and its availability in remote areas will ultimately reduce the use of diesel fuel for power generation, will result in lower-cost, cleaner burning fuel, reduced emissions from trucks, and the reduction of road use to transport the diesel to remote villages.

Photo: Paul Glavinovich, NANA

Figure 6. ***Helicopter transport of drilling supplies can elimate road building to remote sites.***

PRODUCTION

Research and demonstration of new and "best practice" production technologies sponsored by the DOE E&P program in recent years have concentrated on improved recovery efficiency, CO2 sequestration, downhole oil/water separation, and strategies to minimize water production. Demonstrations have focused on strategies and technologies for waterflooding, CO2 floods, steamfloods and monitoring of fluid migration between wells.

BENEFITS:

New processing technologies applied to old seismic data has proven to be a valuable exploration method to comply with environmental regulations, which have halted seismic surveys in some sensitive areas. This means of combining old data with new methods coupled with improved offshore operations can allow development to continue is otherwise restricted areas without harming marine mammals.

Venoco, Inc. of Carpenteria, CA is using modern technologies to continue to explore and produce from offshore areas and to significantly reduce the volumes of produced water that must be disposed of. New seismic reprocessing technology and modeling simulations have allowed Venoco to use data collected from the Santa Barbara Channel over 20 years ago (seismic surveys have been forbidden since 1982) to make discoveries of 80 million barrels of reserves with no adverse impact to the sea mammal population.

Advances in production and drilling using multiple horizontal wells from a single offshore operating platform (**Figure 7**) reduce the surface disturbance at South Ellwood Field. The University of Southern California has developed a model which allows visualization of the subsea reservoir, and identification of the optimal location for wellbores, reducing the number of wells needed to achieve maximum production. The fracture modeling has also been used to identify the seafloor fractures in the Santa Barbara channel, which release gas bubbling to the surface. The collection of gas by concrete seep tents is credited with lowering the gas pressure from the seeps and decreasing the surface oil accumulation, resulting in cleaner beaches and surface waters and healthy marine mammal populations in the Santa Barbara Channel.

Figure 7. ***Cleaner water in Santa Barbara Channel attracts seals to Holly Platform.***

Thru-tubing bubble and plug back technology developed by Schlumberger and tested at South Ellwood Field has resulted in a 10-fold reduction of produced water brought to the surface for disposal. The technology allows the drilling operator to pinpoint exactly where in the horizontal wellbore that water and hydrocarbons enter, and has allowed setting bridge plugs to shut off a significant portion of the water producing intervals. The project plans installation of compact oil/water separation units (developed by a DOE project at the University of Tulsa) on Holly Platform as an additional means to manage produced water. This will allow direct reinjection of the produced water to deeper formations, and avoid bringing any waste water onshore for separation and disposal.

BENEFITS:

The Gas Seep tents first built in the Santa Barbara channel by ARCO were designed as method to collect the gas coming from a large active fault in the San Andreas Fault system. The gas collection provided a marketable product, but more importantly it has noticeably cleaned the waters of the Santa Barbara channel, eliminating large spread oil sheen, reducing tar balls on the beach, and resulting is an increased sea mammal population. The new fracture modeling software used with the reprocessed seismic data has led to identification of new seeps, which can now be covered by Seep tents to further benefit the marine and coastal environment.

BENEFITS:

A major goal of DOE's petroleum Environmental solutions program is the beneficial use of byproducts of energy production. Combing the efforts and byproducts of several industries to reduce waste and provide improved production and profits for these companies is an innovative way to approach regional resource problems. Using the waste products from power generation and ethanol production, which resulted in the past in venting heat and CO_2 to the atmosphere, is now providing enhanced oil recovery, and agricultural products

The University of Kansas/Kansas Geological Survey is demonstrating the enhanced recovery and environmental benefits of carbon dioxide injection in the first CO_2 miscible flood demonstration in Kansas at Hall-Gurney field (**Figure 8**). In a combined effort using local resources, an electrical co-generation facility, an ethanol fuel production plant and several agriculture concerns have joined the CO_2 enhanced oil recovery project to form a linked energy system. Waste heat from a 15-metawatt gas-fired turbine municipal generator and CO_2 (a fermentation process byproduct of ethanol production), which would have been vented to the atmosphere, are being beneficially used or sequestered in the subsurface. Additional heat and by-products are used to process wheat and produce cattle feed. CO_2 injection may prevent up

to 6,000 mature oil fields in Kansas from being abandoned. The University's effort to bring the six co-operating companies together has benefited all by increasing productivity, lowering costs, and by reducing pollution of waste gases.

Photo: Alan Byrnes, Kansas Geological Survey

Figure 8. ***The proximity of Hall-Gurney field, a new electrical power plant and an ethanol plant at Russell, Kansas contribute to innovate use of byproducts in a linked energy system.***

BENEFITS:

Targeted exploration and drilling technologies can result in higher oil production with both fewer dry holes, and a smaller number of wells drilled. Reservoir characterization of fractured reservoirs has led to innovative production strategies, which can produce significantly more oil while reducing the total number of wells drilled.

Pioneer Natural Resources and Texas A&M University have determining a cost-effective way to waterflood highly fractured clastic reservoirs in the Spraberry Trend. The Spraberry, once referred to as, "The largest uneconomic field in the world" covers over one half million acres in the Permian Basin of West Texas. Low recovery (10%) from the Spraberry Trend with its 8 billion bbl remaining oil-in-place marked it as a target for enhanced oil recovery. The fractured nature of the reservoir had made previous waterfloods only marginally successful, precluded CO_2 flooding, and resulted in a lack of confidence in the waterflooding. The revised waterflood technology has increased performance 6-fold, and will be applicable to a significant number of leases in the 250,000 sq. mile Spraberry Trend and is estimated to recovery an additional 15% of OOIP over the next 20 years. Environmentally the successful waterflood technology will mean fewer dry holes in the establishment of waterflood patterns and longer production from each well, reducing the number of wells drilled.

BENEFITS:

A major factor in enhanced recovery has always been transportation costs and facilities, pipelines or roads. Enhanced recovery using nitrogen reduces the need to construct pipelines, normally used to carry injectants. On-site production of nitrogen for enhanced recovery means less land distributed by pipelines, roads, and storage facilities.

Binger Operations of Cody, Wyoming is using nitrogen injection and horizontal wells to increase production and reduce the number of wells needed to produce the East Binger Unit in western Oklahoma. Nitrogen has several advantages over carbon dioxide as an injectant for small, local fields. Nitrogen gas is widely available, cost-effective and environmentally superior for miscible floods. Because nitrogen can be produced locally at on-site generation facilities (**Figure 9**), it can be used where there are no close sources of carbon

Photo credit: Gary Walker, NETL

Figure 9. ***The on-site nitrogen delivery system reduces the footprint in western Oklahoma by eliminating unnecessary pipelines and roads***

dioxide. The lack of pipelines and transportation costs and associated environmental impacts makes nitrogen injection attractive for small fields.

OPERATIONS

Operational considerations in the recovery of oil and gas are often the economic factors that make or break energy production. Reducing the cost of operation and increasing efficiency is vital to operators from marginal fields to offshore platforms. Issues such as electrical power, targeted drilling, separation of oil/gas/water, and improved monitoring of fluids are critical to success and can significantly reduce the environment impact.

BENEFITS:

California air quality standards are high and meeting them is a challenge to producers. Historically waste gas has been flared adding to pollution. Current regulations call for disposal of waste gases. The added value of finding a beneficial use for waste gas avoids the cost of disposal, reduces pollution and provides a cost-effective means to power on-site utility needs.

The California Oil Producers Electricity Coop (COPE) is working with the Interstate Oil and Gas Compact Commission (IOGCC) to demonstrate that existing proven distributed generation technologies, utilizing flare and waste gases as a fuel source, can be applied to generate electricity at marginal well sites. The project is improving the economics of production and decreasing the demand on California's electrical grid. Marginal oil wells in California produce some gas, but not in sufficient quantities to be commercial. The gas becomes a by-product that has to be managed or disposed of some way, using it to run generators will provide power to operate the site. COPE selected a variety of wells producing different amounts and types of gases in Southern California, and different generators to determine those best suited for each well. COPE's demonstration of the first on-site gas powered electrical generation unit is being conducted in Los Angeles. COPE's goal is to reduce air emission to meet Air Quality standards in Southern California, and to reduce production costs so that marginal wells can continue to be economically operated by independents.

BENEFITS:

On-site disposal of waste products is also an important cost savings and environmental benefit for producers. The on-site separation of waste streams and oil and gas allows for immediate reinjection of produced water and avoids the potential problems transporting produced water away from the well site for disposal. Reducing the size and increasing the efficiency of oil/water and gas/water separators makes their use on crowded offshore platforms feasible.

The University of Tulsa working with the Joint Industry Project (JIP) Consortium has developed several refinements for gas-liquid separation and drill cuttings transport of particular use to offshore drilling and production projects in the Gulf of Mexico. The Gas Liquid Cylindrical Cyclone was developed to achieve optimal separation of gas and liquids, in a compact, portable model. The goal is to provide the petroleum industry with a less expensive, more efficient separation alternative to reduce the cost of handling, transporting and processing fluids. The compact size and reduced weight of the unit is ideal for offshore installations yielding a small footprint and allowing for immediate on-site disposal of produced water. The University of Tulsa is currently engaged in the extension of the original GLCC concept (gas-liquid separation) to three-phase flow separation of gas-oil-water.

BENEFITS:

Non-invasive technologies that can monitor water movement are a management tool that will be increasingly valuable for coalbed natural gas development. Coalbed natural gas production results is large volumes of groundwater brought to the surface, much of it is stored in impoundments for beneficial use or infiltration into the subsurface aquifers. The quality of the produced water may be questioned and its containment must be monitored. The ability to trace the movement of the produced water and the natural aquifer waters of an area will assist in management.

NETL-Pittsburgh and the University of Pittsburgh are implementing aeromagnetic surveys of

coalbed natural gas development in the Powder River Basin, Wyoming to monitor groundwater flow. The survey technique uses helicopters to fly over a portion of the Powder River Basin to monitor ground water and produced water flow away from infiltration basins and containment basins. By 2003 over 26,000 coalbed natural gas wells in Wyoming have produced 1 billion cubic feet of natural gas and 1.6 million barrels of water creating a challenge to the oil and gas industry as well as federal and state regulators. Ground water movement is monitored using airborne electromagnetic surveys, GIS to locate positions, and ground conductivity surveys (**Figure 10**) to map near-surface aquifers and produced water plumes. The surveys can identify leaking containment basins several months before a problem is visible to ground personnel. The potential for early detection of leaking containment areas and movement of dissolved salts is a positive environmental benefit in the sensitive Powder River Basin. Information can be used to find and remediate water flow problems, to determine future location for impoundments and groundwater monitoring wells, and to predict water movement allowing coalbed natural gas development to proceed with reduced environmental impact.

Photo credit: Terry Ackman, NETL

Figure 10. ***Ground conductivity surveys coupled with aeromagnetic surveys in the Powder River Basin monitor ground water movement.***

CONCLUSIONS

Exploration and production technologies for the petroleum industry are developed primarily to increase oil recovery and reduce the cost of recovery. Reducing costs often goes hand and glove with reducing the environmental impact of exploration, drilling and completion procedures. The industry search for advanced technology to produce oil and to meet environmental regulations has developed new, improved techniques and strategies which accomplish both goals. Conducting operations that are *"Smarter, Farther, Deeper, Cleaner and Smaller"* makes good business sense and helps to protect the environment. Many oil companies have learned that going that one step farther to protect sensitive environments and avoid pollution, pays them back in increased benefits and improved public relations.

The selected E&P projects from DOE's oil program highlight some of the kinds of technologies and innovative strategies being used in mature US oil fields to increase production cost-effective ways that have environmental benefits. The impact of advanced technologies for exploration, drilling, production and oilfieldd operation can be seen in reduced footprint, reduced air pollution, better monitoring of fluids to prevent loss or pollution, and on-site recycling of energy byproducts to reduce unnecessary pipelines and roads. For more details on these projects, visit the Recent Project Success - Fact Sheets at www.npto.doe.gov

Nominations are being taken for the 2004 Chairman's Stewardship Awards
Honoring the Oil & Gas Industry's commitment to Environmental Stewardship

The Interstate Oil and Gas Compact Commission 2004 Chairman's Stewardship Awards. The winners will be honored at the IOGCC Annual Meeting in Oklahoma City, Oklahoma, Oct. 17-19, 2004. You may nominate your company or organization, or any group that has made a contribution in one of the following categories:

- Major Company
- Independent Company
- Energy Education
- Environmental Partnership

To submit a nomination, contact Alesha Riggle at 405.525.3556, ext. 114. Log on **www.iogcc.state.ok.us** for more information and to see past recipients. Deadline for accepting nominations is August 23, 2004.

Upcoming Events/Meetings

Jan. 30-Feb. 2, 2005, Gas Technology Institute (GTI), *Technology Need and Operational Issues of the Natural Gas Industry*, Orlando, FL, (847) 768-0842 Fax, **www.ngt2005@gastechnology.org**

Oct. 12-15, 2004, International Petroleum Environmental Conference (IPEC), *Issues and Solutions in Exploration, Production and Refining*, Albuguerque, NM **http://ipec.utulsa.edu**

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EoE features highlights of DOE's Oil and Gas Environmental Research Program.

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